Chapter V

Alpha Decay Study of Super heavy Nuclei in the mass region
A=258-320

5.1 Existence of Super heavy Nuclei

There are 81 stable element and about 300 stable nuclei existing on the earth. About 2,200 nuclei have been made artificially. Making heavier nuclei by artificial process is very difficult because the disruptive electrostatic force between positively charged protons increases rapidly with atomic number in comparison with the cohesive nuclear forces that hold the nucleons together. Super heavy nuclei are the heaviest element that populate beyond the boundary of the periodic table and are inhabited in upper right corner of the nuclear landscape but limit of their territory are unknown. Because of large electrostatic forces emission of alpha particle and spontaneous fission are the main decay modes in super heavy region. The interplay between strong and electrostatic forces is responsible for the structure of super heavy element. In case of super heavy nuclei coulomb interaction can not be treated as small perturbation to the dominating nuclear interaction and it influences proton and neutron distribution significantly. Each unstable isotope is characterized by its half life. Half life of the isotopes ranges from less than thousandth of a second to billions of year. Some nuclei have half life comparable to the age of the earth however some are short lived. Short lived isotopes are not found on the earth. Thousands of short lived isotopes are continually created in cosmos. Though their existence is small but they play major roll in formation of the elements in the universe. Some stable nuclei exist beyond the chart of nuclides because of closed proton and neutron shells. It is observed from the theories and later approved by the experiments that after achieving certain configuration of proton and neutron lives of nuclei will be longer. A nucleus with completely filled proton or neutron shell is called as magic nuclei because it is more stable than its neighboring nuclei. Most of the magic nuclei are spherical in shape but some can lower their energy and hence increase their stability by rearranging
proton and neutrons into deformed shells accommodating a different number of nucleons. The closing of these deformed shells lead to deformed magic number. Advanced computer program and accelerator based research are very helpful in understanding the structure and stability of super heavy nuclei. The shape of the super heavy nuclei can help in determining the stability or life of the nucleus. A typical life time of super heavy nucleus is of the order of millisecond. A super heavy nucleus may be much more stable or long lived depending on the shape of the nuclei. The specific feature of super heavy nuclei is that it does not exist in terrestrial material because of radioactive decay but they can be produced artificially in neutron capture and heavy ion induced reactions [Fle 81].

Starting from uranium and thorium the lifetimes of the nuclei of known element decreases with increase in their atomic numbers. For example isotopes of elements 106 & 107 have half lives ranging from one second to one millisecond [Oga 74, Oga 76, Ghi 74, Mun 81a]. The tendency of decreasing lifetime continues in the region of heaviest elements.

5.2 Experimental Status

Beyond actinides (Z=89-103) there exist a region where one can find super heavy elements with large life times. This region of super heavy elements in the region $250 \leq A \leq 320$ is called as magic island or island of instability. Because of the progress in accelerator based research, experiments and theoretical nuclear models it has been possible to discover SHE across the island of instability. By using radioactive Ion Beam (RIB) facilities one can reach to the ultimate magic island where the neutron rich SHE resides. Most of the heavy and super heavy elements have been discovered in Lawrence Berkeley Laboratory (USA), Joint Institute of Nuclear Research in Dubna, Gesellschaft fur Schwerionenforshung (GSI) in Germany and RIKEN (Japan). Study of super heavy nuclei began in 1940s with the synthesis of heavy elements, neptunium (Z=93) and plutonium (Z=94) having atomic number greater than the uranium (Z=92). Americium (Z=95) and curium (Z=96) were synthesized in 1944, berkelium (Z=97) in 1949. Californium (Z=98), einsteinium (Z=99) and fermium (Z=100) in 1952 and mendelevium (Z=101) were synthesized in 1955 [Eur 02]. These entire ranges of heavy elements have been produced by neutron irradiation or by bombardment of proton, deuteron or alpha proton.
particle in a cyclotron with the exception of the fermium nucleus in which in turn was formed through the capture of 17 neutrons by $^{238}\text{U}$ followed by the subsequent beta decays. In nature a similar process called as r-process takes place in supernova which is responsible for the synthesis of heavy elements in nature. First observation on super heavy nuclei has been made in early 1980’s for the element with Z=107-109 and later alpha decay chain have been experimentally detected from $^{269}\text{110}$, $^{271}\text{110}$, $^{272}\text{111}$, $^{277}\text{112}$ and $^{283}\text{112}$ [Arm 03, 85; Hof 07, 00, 98]. It was observed that these elements have very short life time. For example $^{277}\text{112}$ have half life of the order of 300 $\mu$s. Recently the doubly magic deformed $^{270}\text{Hs}$ (Z=108, N=162) super heavy nucleus has been produced [Dvo 06]. The element Dramstadtium (Z=110) was confirmed in 2002 by independent work of Lawrence Berkley Laboratory (USA) [Gin 03] and Institute of Chemical and Physical Research (RIKEN) in Japan [Mor 04a]. Z=111 and Z=112 were also confirmed at RIKEN. Later scientists of the RIKEN have reported synthesis of $^{278}\text{113}$[Oga 04]. It is observed that production cross section decreases with increasing atomic number. Thus it has been very difficult to discover heavier element in cold fusion reactions using lead or bismuth targets. By using hot fusion reaction with $^{48}\text{Ca}$ beam and actinides target several new element with Z=113-116 and 118 and several new isotopes of Z=110 and 112 have been discovered at Joint Institute of Nuclear Research Dubna (Russia). Recently new nucleus Z=117, A=293,294 have been synthesized in Dubna [Oga10]. None of these experiment have reached the N=184 region as yet. The most important thing observed is that half life of an isotope increases with increasing neutron number. For example in going from $^{282}\text{112}(\text{N}=170)$ to $^{285}\text{112}(\text{N}=173)$, the half life increases from 1 ms to 34 sec [Oga 04a].

5.3 Experimental methods for the production of Super Heavy Nuclei

To understand the territory of the island of stability, predicted by theoretical models scientists have been motivated to synthesize the heaviest or super heavy nuclei. Synthesis of nuclei in the island of stability is very difficult, because the nuclei available for target and projectile do not provide the necessary number of neutrons. Also the experimental problem starts with increasing atomic number, because the production cross section decreases exponentially with increase in atomic number. From the literature it is known
that heaviest nuclei have been synthesized in heavy-ion fusion reactions. In this process a compound nucleus is formed with some excitation energy. On the basis of excitation energy of compound nucleus and their survival probability in the process of neutron emission, this reaction has been classified into two classes (i) cold fusion reaction and (ii) hot fusion reaction.

(i) Cold fusion reaction:

In this class of reaction when heavy target $^{208}\text{Pb}$ or $^{209}\text{Bi}$ get fused with massive projectile nucleus (A=50-70) a compound nucleus is formed with excitation energy of $E_x=20-11$ MeV and evaporation product is obtained with $Z=104-112$ [Oga 88; Hof 00; Mor 04a, 04b]. Transition of this nucleus to the ground state takes place through the emission of only one neutron and gamma rays. This is the main advantage of this reaction. As the projectile ion mass increases, the cross section for the formation of the evaporation product decreases sharply owing to the appearance of limitations on fusion already in the entrance channel of the reaction. For the first time using the cold fusion reaction the elements with atomic number $Z=107-112$ were synthesized and also their radioactive decay were investigated.

(ii) Hot fusion reaction with $^{48}\text{Ca}$ ions:

In this class of reaction heavy actinide are used as target and $^{48}\text{Ca}$ as projectile. After fusion a compound nucleus is formed with excitation energy 30-40MeV, which is called hot fusion reaction. In this case the formation of the compound nucleus competes with strongly asymmetric fission. Transition of this compound nucleus to ground state takes place through the emission of three or four neutrons and gamma rays. This reaction exhibit low survival probability because of fission that interrupt the cooling process through the sequential emission of neutrons. The main reason of the choice of neutron rich isotope $^{48}\text{Ca}$ as projectile and $^{244}\text{Pu}$ and $^{248}\text{Cm}$ as the target is to obtain compound nuclei with $Z=114-116$ and $N=178-180$ near the closed shell $Z=114$ and $N=184$. This reaction has been used for the synthesis of heavy nuclei with $Z \geq 112$, where cold fusion reaction is at the limit of experimental possibilities.
5.4 Theoretical status

For the first time realistic theoretical calculations for the super heavy nuclei were started in 1966. These calculations were based on the shell correction (or macroscopic-microscopic) method. These calculations have been used to predict the nucleus with $Z=114, N=184$ ($^{298}\text{Uu}_{114}$), which has been recognized to be doubly magic centre of an island of long lived super heavy nuclei. Later in 1990s more refined model, based on self consistent mean field theory and realistic effective nucleon-nucleon interactions, were used in the study of super heavy nuclei. By using theoretical model it has been observed that existence of nuclei with $Z >102$ are entirely due to quantal shell effects. According to classical liquid drop model, the shape of the nucleus depends on the interplay between surface tension and Coulomb force of electrostatic repulsion. The characteristic of surface tension is to make the nucleus spherical and is proportional to $A^{2/3}$, and characteristic of Coulomb repulsion is to make nucleus deformed and is proportional to $Z^2/A^{1/3}$ [Eur 02]. At large values of $Z^2/A$ the Coulomb force of repulsion becomes strong enough to make the liquid drop unstable to surface distortions and nuclei fissions spontaneously [Boh 39, Fre 39]. Using theoretical models for the heaviest elements excellent agreement with the experimental data have been observed, however large theoretical uncertainties can be seen in the unknown regions of nuclear chart. There is no particular opinion among the nuclear physicists regarding centre of the shell stability in the super heavy region. Since in the super heavy nuclei the single particle level density is relatively large, small shift in the position of single particle due to the Coulomb or spin-orbit interaction can be crucial for determining the shell stability of a nucleus. Most of the macroscopic-microscopic or self consistent approaches have predicted $Z=114$ to be magic after $Z=82$. Self consistent methods suggest that the centre of the proton shell stability should be shifted to higher proton numbers, $Z=120,124$ or 126. However for neutrons most non relativistic calculations predict $N=184$ as magic number while the relativistic mean field theory predicts magic number at $N=172$ due to slightly different spin-orbit interaction and predicts deformed proton magic number at 110 and deformed neutron magic number at 162. According to microscopic nuclear theories there is a significant enhancement in nuclear stability when approaching the closed spherical shell with $Z=114$ or $Z=120$ and $N=184$. Myres and Swiatecki [Mye 65] observed that the shell corrections added to liquid
drop model indicates the possibility of closed shell at Z=114 and N=184 which was latter confirmed by A.Sobiczewski et al [Sob 66]. In 1969 Nilssion et al [Nil 69] predicted that the longest fission half life around the nucleon number Z=114, N=184 and the stability against spontaneous fission in this region is due to extra binding resulting from the shell effect which essentially increases the alpha decay half life for nuclei with Z<114, N<184 and decreases for those with Z>114, N>184.

Discovery of super heavy nuclei has opened a vast area of understanding of the structure of nuclei. One of the major goals of the nuclear theory is to develop a nuclear model and semiempirical formula to be able for the prediction of the life time of super heavy element. Employing more appropriate alpha –daughter potential and by using more appropriate nuclear model, half life of the super heavy nuclei can be calculated and a clue can be given to the experiments pursuing on super heavy elements. On the theoretical front several attempts have been made to calculate the alpha decay half lives of SHE using different approaches. In the microscopic approach using double folding model Samanta et al [Sam 07] have calculated alpha decay half life in the region Z=102-116, 118. These authors have used Viola Seaborg formula to calculate alpha decay half life for the comparison. Chowdhary et al [Cho 07] have calculated alpha decay half life of Z=113 and its decay products using experimental Q values for $\ell = 0$ and $\ell = 5$, mutual angular momentum states respectively and later Chowdhary et al [Cho 08a] have also calculated alpha decay half life in the region Z=102-120. Later Samanta [Sam 07a, Sam 09] and Chowdhary et al [Cho 08a, Cho 08b] have predicted alpha decay half lives of isotopes in the region $100 \leq Z \leq 130$ and obtained good agreement with the experimental data of experimentally known isotopes. Z.Z. Ren et al [Ren 07] have calculated alpha decay half life, alpha decay energies and spontaneous fission half life of super heavy nuclei for the several isotopes in the region Z=106-118 and have obtained good agreement with the experimental data.

Generalized liquid drop model (GLDM) and Coulomb plus proximity potential model (CPPM) are two macroscopic approaches, which are commonly used to develop a potential barrier for alpha-daughter system. G.Royer et al [Roy 02] have calculated alpha decay half life in the region Z=104-118 and A=250-302 using GLDM and phenomenological formula and later they have predicted half lives in the region Z=112-
126 and A=270-323 [Roy 04] using same model. Q values have been calculated by using Thomas Fermi model. Zhang et al [Hon 06] have used Generalized liquid drop model (GLDM) to calculate alpha decay half lives for experimentally observed nuclei Z=112,114,116,118 and have also used their model to predict the half lives of several isotopes in the region Z=105-120 [Zha 07]. Q values have been calculated by using finite range droplet model (FRDM). Good agreement has been found with experimental data. Santhosh et al [San 09] have made comparative study of alpha decay and spontaneous fission half life in the region Z=100-122 by using CPPM model. They also have found good agreement with the experimental data. Using the effective liquid drop model approach Duarte et al [Dua 04] have predicted alpha decay half life in the region 110≤Z≤135 and 155≤N≤220. Dong Jian Min et al [Don 08] have calculated alpha decay half life of some isotopes of Z=113 and some of their alpha decay products using GLDM and Cluster model approach. Both the models are successful to reproduce the experimental data for the calculations corresponding to mutual angular momentum ℓ = 0 state. They have included the nonzero mutual angular momentum state also through the centrifugal effect and show the significant effect of nonzero angular momentum on the half lives of SHN. In almost all the cases discussed above Qα values has been taken either experimentally or by phenomenological mass formula of Myres-Swiatecki, Muntian and KUTY.

In an alternative approach Sahu [Sah 08] have used the wave function method for evaluating the alpha decay half lives of super heavy nuclei in the region Z=106 -118. In yet another approach Prema et. al. [Pre 08] have used S-matrix formulation for the calculation of alpha decay half life of super heavy nuclei Z=110, A=269 and Z=112, A=277. Gambhir et al [Gam 03] have calculated ground state properties and alpha decay half life of the decay chain of Z=112 in the framework of relativistic mean field theory.

In the present work we have studied alpha decay half life of super heavy nuclei in the region Z=106-128 and A=258-320 for their ground state to ground state transition with mutual angular momentum ℓ = 0 in a unified fission like approach. We have used a highly versatile, asymmetric and analytically solvable form of alpha-daughter potential based on Ginochio’s potential developed by Sahu [Sah 02] which has been described in
chapter III. For the calculations exact expression of transmission probability given by eq. (3.11) has been used in place of commonly used WKB approximation method.

5.5. Model parameter

In the present work to generate a potential barrier for alpha decaying system we have fixed $\lambda_1 = 3$ and $\nu_1 = 2.2$ in the inner region and $\lambda_2 = 1.2$ in the outer region and $\nu_2$ has been varied to obtain the experimental half lives. For the radial position and height of the potential barrier we have used a global formula given by [Sah 99]

$$ R_B = r_0 \left( A_1^{1/3} + A_2^{1/3} \right) + 2.72 $$

$$ V_B = \frac{Z_1 Z_2 e^2}{R_B} \left( 1 - \frac{a}{R_B} \right) $$

Where $A_1, A_2$ and $Z_1, Z_2$ are the mass numbers and atomic numbers of the alpha and daughter nuclei respectively. $r_0$ and $a$ are two distance parameter and $e^2 = 1.4398$ MeV fm. Parameters are fixed at $r_0 = 0.9$ fm and $a = 1.6$ fm for our system of interest [Sah 08]. Barrier height for each isotope has been calculated separately and ranges from 25.3450 MeV for $\alpha + {}^{262}\text{Rf}$ system to 30.0218 MeV for $\alpha + {}^{302}\text{Sg}$ system. The decay rate has been calculated by $P = P_0 T$. Where $P_0$ is the assault frequency and $T$ is the transmission coefficient across the barrier. The assault frequency $P_0$ is calculated from the zero point vibration energy $E_\nu = \frac{1}{2} \hbar P_0$ [Poe86], which in turn depends directly on $Q$ value of decay. Results are shown in table 5.1. The half life $t$ is calculated as $t = \log_e 2/P$.

5.6 Result and discussion

In the present work we have calculated the alpha decay half lives of ${}^{256}\text{Rf}_{104}$, $^{260}\text{Sg}_{106}$, $^{266}\text{Sg}_{106}$, $^{264}\text{Hs}_{108}$, $^{286}114$, $^{288}114$, $^{290}116$, $^{292}116$ and $^{294}118$ for ground state to ground state transition with mutual angular momentum $\ell = 0$, using an analytically solvable asymmetric potential that admits exact solution for the transmission coefficients.
Calculations have been performed by varying the range parameter $\nu_2$ so as to obtain the best fit to the experimental half life. Results are shown in table 5.1. Good agreement has been obtained with the experimental data by variation of just one parameter $\nu_2$. Plot of the resulting potential barrier for two nuclei $^{260}\text{Sg}$ and $^{292}\text{116}$ are shown in figure 5.1. In the phenomenological formula of Geiger-Nuttal and VSS [Sob 89] or in any other semiempirical relation of half life and decay energy the logarithm of half life is proportional to $Z/\sqrt{Q}$ in the leading term. Also it is expected that logarithm of half life should be directly proportional to the width of the barrier defined by range parameter $\nu_2$.

From table 5.1 it has been observed that $\left(\nu_2\sqrt{Q}\right)/Z$ is nearly constant for most of the isotopes. Thus a semiempirical formula $\nu'_2 = \frac{Z}{Z} \sqrt{Q/\sqrt{Q}} \times \nu_2$ has been used to calculate range parameter $\nu'_2$ for the unknown super heavy nuclei. $\nu_2$ corresponding to minimum $Q$ value is taken as a base value for the calculation of $\nu'_2$, and theoretical $Q_\alpha$ values calculated from KUTY mass estimate [Kou 05] have been used in the calculation of half lives of unknown super heavy nuclei. To test the accuracy of this formula alpha decay half lives of experimentally known nuclei have been calculated corresponding to the range parameters $\nu'_2$, calculated by semiempirical formula. Calculated half lives are compared with the earlier studies and with the experimental data. Results shown in table 5.2 are in good agreement with the experimental data and other studies for all cases. In some of the cases, our results are in closer agreement with experimental data than those obtained with DDM3Y. This shows the reliability of the semiempirical formula.

Santhosh et al [San09] have made a comparative study of spontaneous fission (SF) and alpha decay half lives of super heavy elements for $Z=100-122$. We have extended these calculation for the chain of $Z = 124$; $A = 288-312$, $Z = 126$; $A = 292-318$ and $Z = 128$; $A = 294-324$. SF half has been calculated by using phenomenological formula of Ren [Ren05] given as

$$\log_{10}(T_{\nu_2}) yr = 21.08 + C_1 \frac{(Z - 90 - \nu)}{A} + C_2 \frac{(Z - 90 - \nu)^2}{A} + C_3 \frac{(Z - 90 - \nu)^3}{A} + C_4 \frac{(Z - 90 - \nu)(N - Z - 52)^2}{A}$$

Where $C_1 = -548.825021, C_2 = -5.359139, C_3 = 0.767379$ and $C_4 = -4.282220$.
The seniority term $v$ was introduced taking the blocking effect of unpaired nucleon on the transfer of many nucleon-pairs during the fission process and $v = 0$ for spontaneous fission of even-even nuclei. The results are shown in fig. 5.2-5.4. In the chain of $Z=124-128$ predicted alpha half life is of the order of $10^{-5}$ sec. to $10^{12}$ sec, however predicted maximum SF half life is of the order of $10^{46}$ sec to $10^{72}$ sec. SF half life versus mass number curve is in the shape of inverted parabola whereas alpha decay half lives vary as straight lines. SHE which lies within the point of intersection of the two curves would decay prominently by alpha emission. We have predicted alpha decay half life of unknown even-even super heavy nuclei in the region $Z=106-122; A= 258-304$ and $Z=124-128; A= 292-320$. As half life of a nuclei for a particular decay mode strongly depends on the $Q$ value of the decay. In the present work for unknown $Q_\alpha$ values we have used $Q$ values calculated by using KUTY mass estimates. The result of ref. [Cho08b] obtained with DDM3Y interaction are also given for comparison. Our predicted result shows very small deviation with ref [Cho08b], however in some cases they are very close to the result of ref [Cho08b]. The plot of decay energy $Q_\alpha$ and alpha decay half life against mass number of parent nuclei for $Z=106-128$ are shown in fig. 5.5-5.16. From the plots we have observed that in the chain of $Z=106; A=258-272$, half life ranges from $1.05 \times 10^{-4}$ sec to 104.41 sec, in the chain of $Z=108; A=262-278$, half life ranges from $1.74 \times 10^{-5}$ sec to 733.27 sec, for $Z=110; A=268-286$, half life ranges from $7.7 \times 10^{-6}$ sec to $3.51 \times 10^{8}$ sec, for $Z=112; A=272-290$, half life ranges from $2.18 \times 10^{-6}$ sec to $5.99 \times 10^{7}$ sec for $Z=114; A=274-298$ half life ranges from $2.39 \times 10^{-7}$ sec to $1.10 \times 10^{9}$ sec and for $Z=116; A=278-302$ half life ranges from $5.90 \times 10^{-8}$ sec to 19.20 sec. Thus it has been observed that alpha decay half life increases with increasing neutron number but decreases with increasing proton number. The isotopes which are short lived are stable against spontaneous fission or may decay via spontaneous fission with very large of the order of several year of spontaneous fission half life. These isotopes have alpha decay as dominant decay mode and can be synthesized in the laboratory [San09]. In the region for $Z>116$ in the isotopic chain of $Z=118-128; A= 280-320$ half life ranges from $3.46 \times 10^{-12}$ sec for $^{314}128$ to 0.33 sec for $^{302}118$. This decreasing trend of half life values with increasing $Z$ shows that alpha decay becomes more dominant decay mode for the higher
Z values in the super heavy region. Thus in the region Z=114-128 highest half life has been observed at Z=114 and N=184, which is recognized as doubly magic nuclei.

Relativistic mean field calculation on SHE [Rut 97, Ben 99] suggest that after Z=82 next proton and neutron magic number are at Z=114,126; N=184 and Z=120, N=172. But some recent microscopic nuclear theories [Sto 06] point out the island of stability centered around Z=114,120,124,126 and N=184. It is clear from figs. 5.12-5.15 that in the chain of Z=120; A=284-306, highest half life is observed at N=184, reflecting the shell closure effect. In the chain of Z=122; A=284-304, and Z=124; A=292-310 highest half life has been observed at N=178. Also in the chain of Z=126; A=298-314, highest half life is observed at N=178. This shows that in super heavy region magic number may change from nucleus to nucleus [Hon 05] as indicated in reference [Hon 06].

In figure 5.17 we have shown the plot for the ratio of logarithm of spontaneous fission half life and logarithm of alpha decay half life versus fissility parameter for Z=124-128 similar to one proposed by Studier et al [Stu 54] and later by Santhosh et al [San 09]. It is observed from the plot that the ratio of half lives increases with increasing fissility parameter reaches to maximum value and then start decreasing with increasing fissility parameter for a particular isotopic chain. It also has been observed that the ratio increases with increasing fissility parameter with increasing atomic number. Similar to ref. [Stu 54, San 09] we have connected the isotopes which are differ in atomic number by two and mass number by six units by a straight line. At a particular point on this line the ratio start decreasing with increasing fissility parameter. The fissility parameter has been calculated by using the relation \[ X = \frac{Z^2/A}{50.883 \left[ 1 - 1.7826 \left( \frac{(N-Z)}{A} \right)^2 \right]} \], where \( Z^2/A \) is fissionability parameter [San 09].
Table 5.1: Calculated and experimental alpha decay half lives of known even-even SHE for ground state to ground state transition with mutual angular momentum $\ell = 0$. Corresponding best fit values of the range parameter $\nu_2$, barrier height, radial position and assault frequency are also given. Experimental data for $^{256}$Rf$_{104}$, $^{260}$Sg$_{106}$, $^{266}$Sg$_{106}$ and $^{264}$Hs$_{108}$ has been taken from ref. [Roy 00] and for other nuclei from ref. [Oga 04, 05, 06].

<table>
<thead>
<tr>
<th>Parent Nucleus ($^A_Z$)</th>
<th>$Q^{\exp}$ (MeV)</th>
<th>Barrier Height $V_B$ (MeV)</th>
<th>Radial position $R_B$ (fm)</th>
<th>Assault freq.$(P_0) 10^{20}$s$^{-1}$</th>
<th>Range parameter ($\nu_2$)</th>
<th>Log$<em>{10}$(t$</em>{1/2}$) Sec Cal. Present work</th>
<th>Log$<em>{10}$(t$</em>{1/2}$) Sec Exp.</th>
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Table 5.2: Comparison of the alpha decay half lives $T_{1/2}$ (ms) calculated in the present work with the experimental data and other work. The value of range parameter $\nu_2$ calculated by using semi-empirical relation is also given.

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<th>$Q^{\text{exp}}$ (MeV)</th>
<th>Range parameter $\nu_2$</th>
<th>$T_{1/2}$ (ms)</th>
<th>Expt.</th>
<th>Present work</th>
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<th>GLDM [Zha 07]</th>
<th>VSS [Cho08b]</th>
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<td>$^{286}\text{Hs}_{114}$</td>
<td>10.35</td>
<td>28.3269</td>
<td>0.16×10$^3$</td>
<td>0.36×10$^3$</td>
<td>6.9</td>
<td>0.05×10$^3$</td>
<td>8.5</td>
<td></td>
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<tr>
<td>$^{288}\text{Hs}_{114}$</td>
<td>10.09</td>
<td>28.6902</td>
<td>0.80×10$^3$</td>
<td>3.09×10$^3$</td>
<td>0.16×10$^3$</td>
<td>0.22×10$^3$</td>
<td>0.22×10$^3$</td>
<td></td>
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<tr>
<td>$^{290}\text{Hs}_{116}$</td>
<td>11.00</td>
<td>27.9574</td>
<td>15</td>
<td>21.3</td>
<td>8.21</td>
<td>3.47</td>
<td>9.55</td>
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<tr>
<td>$^{292}\text{Hs}_{116}$</td>
<td>10.80</td>
<td>28.2142</td>
<td>18</td>
<td>94.8</td>
<td>8.65</td>
<td>10.45</td>
<td>0.10</td>
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<tr>
<td>$^{294}\text{Hs}_{118}$</td>
<td>11.65</td>
<td>27.6339</td>
<td>0.89</td>
<td>1.7</td>
<td>0.14</td>
<td>0.34</td>
<td>0.13</td>
<td></td>
</tr>
</tbody>
</table>
Figure 5.1: Shape of the potential barrier for two nuclei $^{260}\text{Sg}$ and $^{292}\text{116}$.

Figure 5.2: Plot of the calculated spontaneous fission (SF) half life and alpha decay half life with respect to mass numbers of the isotopic chain of parent nucleus Z=124. Full square on the inverted parabola shows the SF half life of the respective nucleus and black circles on line crossing the inverted parabola shows the alpha decay half life of the respective nucleus.
Figure 5.3: Same as figure 5.2 for Z=126.

Figure 5.4: Same as figure 5.2 for Z=128.
Figure 5.5: Plot of Q value of decay and logarithm of alpha decay half life versus mass number of parent nuclei for Z=106.
Figure 5.6: Same as fig. 5.5 for Z=108
Figure 5.7: Same as figure 5.5 for $Z=110$. 
Figure 5.8: Same as figure 5.5 for Z=112.
Figure 5.9: Same as figure 5.5 for Z=114.
Figure 5.10: Same as figure 5.5 for Z=116.
Figure 5.11: Same as figure 5.5 for Z=118.
Figure 5.12: Same as fig.5.5 for Z=120.
Figure 5.13: Same as fig.5.5 for Z=122.
Figure 5.14: Same as fig. 5.5 for $Z=124$. 
Figure 5.15: Same as fig. 5.5 for Z=126.
Figure 5.16: Same as fig. 5.5 for Z=128.
Figure 5.17: The plot connecting the ratio of spontaneous fission to alpha decay half-lives against the fissility parameter for $Z = 124–128$.

5.7 Summary and conclusion
In the present work we have calculated alpha decay half life of experimentally known even-even super heavy element $^{256}Rf_{104}$, $^{260}Sg_{106}$, $^{266}Sg_{106}$, $^{264}Hs_{108}$, $^{286}114$, $^{288}114$, $^{290}116$, $^{292}116$ and $^{294}118$ with experimental $Q$ values by using an asymmetric potential model in the unified fission like approach. Good agreement has been found with experimental data by varying just one single parameter $\nu_2$. To calculate the range parameter $\nu_2$ of unknown systems a semiempirical relation has been developed between range parameter and decay energy. Alpha decay half lives for unknown even-even isotopes in the region $106 \leq Z \leq 128$ and $258 \leq A \leq 320$ have been predicted. In our calculations we have used theoretical $Q$ values calculated by using KUTY mass estimates [Kou 05]. The predicted results of the present model differ from the work of Chowdhary et al [Cho08b], based on microscopic calculations only slightly. Our predicted results are more reliable than the work of Chowdhary et al [Cho08b], calculated by using DDM3Y interaction in the following aspects. (i) We have used exact expression to calculate transmission probability
through the potential barrier instead of commonly used WKB approximation method. The WKB method does not take into account the behavior of the potential in the tail region. (ii) Renormalization effects are incorporated in our model by appropriate choice of $\lambda$ and $\nu$. However it is not incorporated in the work of Chowdhary et al [Cho 08b] and Samanta [Sam 07, Sam 09] and so the form of their potential has sharp peak of Coulomb barrier. The predicted alpha decay half lives of unknown SHE can serve as a guideline for future experiments.